Late Glacial Origin of the Maumee Valley Terraces, Northwestern Ohio[1]

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ABSTRACT. **Four major paired terraces and six short local terraces have been identified along the Maumee River valley between the Ohio-Indiana state line and Perrysburg in northwestern Ohio by detailed field mapping and study of gaging-station records, water-well logs, and soils data. From highest to lowest, the paired terraces have been named the Antwerp, Florida, Napoleon, and Grand Rapids terraces. The three higher terraces are correlated with Glacial Lakes Warren I and II, Lake Wayne, and Lake Grassmere, respectively, based on similarities in elevation of the lowest end of the terraces and the lake levels. The lowest of the four major terraces, the Grand Rapids Terrace, is rock-defended, controlled by outcrops of the Silurian Tymochtee Dolomite in its channel at Waterville. The short local terraces appear to be related to short-lived stages in the cutting of the Maumee Valley. Although some may correlate with one of the major terrace systems, such correlations remain tentative because of the isolation of these local terraces.**

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INTRODUCTION

The Maumee River is the largest river draining northwestern Ohio. It heads in Indiana, and is fed by tributaries in Indiana, Michigan, and Ohio, creating a drainage basin encompassing approximately 19,425 km^2 (7,500 mi^2) (Cross and Weber 1959). The Maumee River flows across a broad, low lake plain formed by ice-dammed lakes in the Erie Basin during the retreat of the Wisconsinan ice sheet (Leverett 1902; Leverett and Taylor 1915; Carman 1930; Forsyth 1966, 1970, 1973; Calkin and Feenstra 1985; Coakley and Lewis 1985; Eschman and Karrow 1985). A history of these glacial lakes (Table 1) and the general positions of their shorelines in northwestern Ohio (Fig. 1) have been determined. The lake plain in northwestern Ohio is underlain by lake-modified till and lacustrine sediments (Forsyth 1965, 1966) which in turn are underlain by Middle Silurian to Upper Devonian rocks which dip gently northwest into the Michigan Basin (Forsyth 1966, Dorr and Eschman 1970, Herdendorf and Braidech 1972).

The Maumee River began as an extended consequent stream flowing across newly exposed lake bottom when the level of Lake Maumee I, first and highest of the late Wisconsinan glacial lakes fell, exposing the western portion of the Erie Basin (Carman 1930). The mouth of the Maumee River alternately extended eastward or became flooded as lake levels rose and fell with shifts in the position of the glacial margin. On several occasions, the ice dam in the Buffalo, NY, area receded far enough north to allow the impounded Erie Basin waters to drain eastward briefly. This caused a temporary but drastic fall in lake level and a resulting extension of the Maumee River eastward across the exposed lake bottom. These events occurred during Arkona (Ypsilanti) stage before the Maumee Valley had formed, during Wayne stage, and probably during Grassmere/Lundy stages (Kunkle 1963, Calkin and Feenstra 1985, Eschman and Karrow 1985). The greatest such eastward extension of the Maumee River, to a point northeast of Erie, PA, occurred during Early Lake Erie stage, when ice retreat at the isostatically low Niagara Escarpment near Buffalo allowed an almost complete emptying of the Erie Basin (Forsyth 1970). Since

TABLE 1

Glacial Lakes in the Erie Basin.

Lake	Elevation	Outlet
Modern Lake Erie	174 m (570 ft)	Niagara
Early Lake Erie	128 m (420 ft)	Niagara
Lundy	189 m (620 ft)	east*
Grassmere	195 m (640 ft)	east*
Warren III	203 m (665 ft)	Grand River
Wayne	201 m (660 ft)	Mohawk Valley
Warren II	206 m (675 ft)	Grand River
Warren I	210 m (690 ft)	Grand River
Whittlesey	225 m (735 ft)	Ubly
Ypsilanti	166 m (545 ft)	Niagara
Arkona	216-212 m (710-690 ft)	Grand River
Maumee III	238 m (780 ft)	Imlay
Maumee II	232 m (760 ft)	unidentified outlet across "thumb" of Michigan
Maumee I	244 m (800 ft)	Ft. Wayne

After Calkin and Feenstra 1985, Eschman and Karrow 1985.
*Glacial Lakes Lundy and Grassmere are believed to have drained eastward (Eschman and Karrow 1985), but the outlets have not been identified, hence the more general term "east," rather than Niagara.

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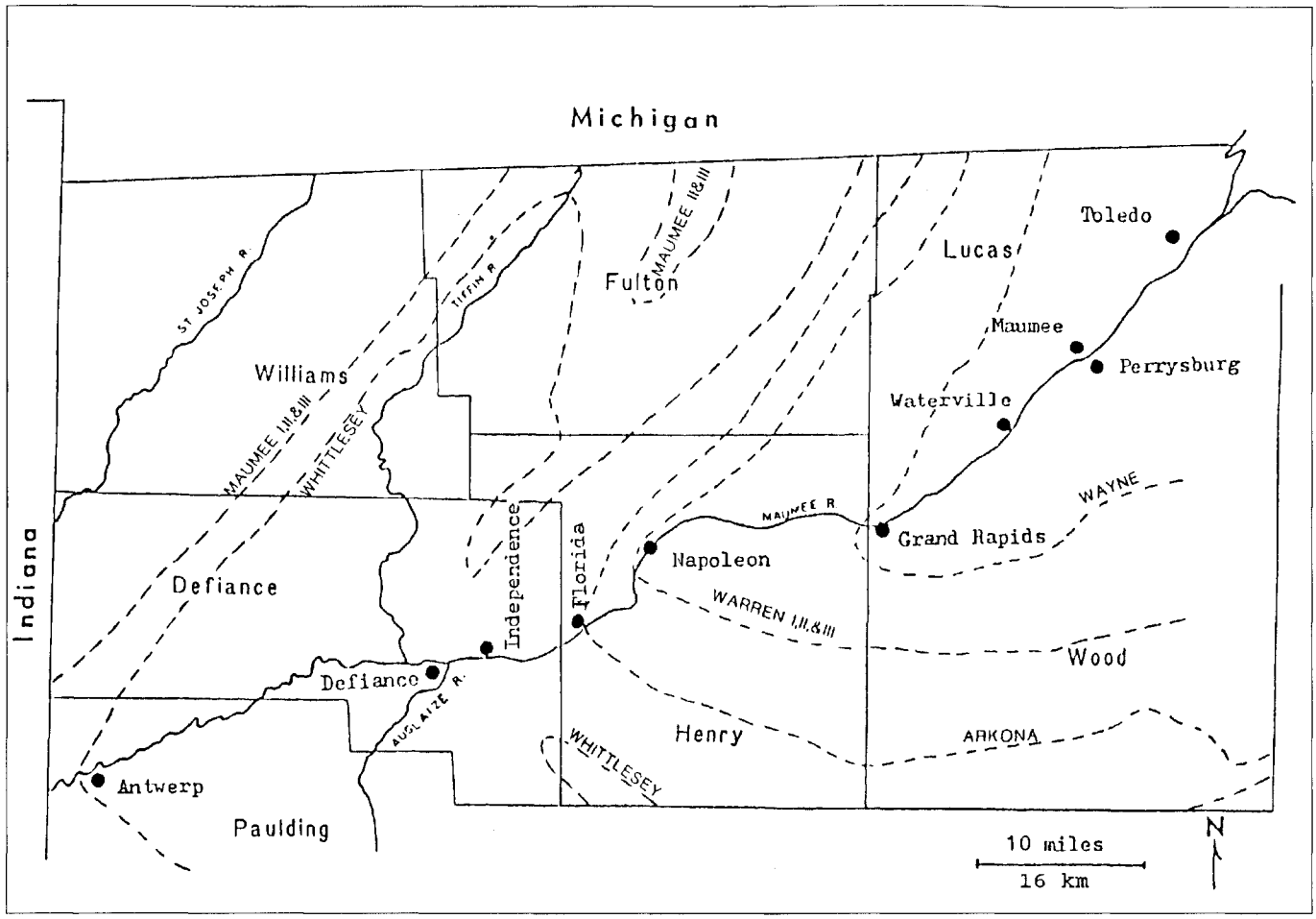

FIGURE 1. Shoreline positions of glacial lakes in northwestern Ohio (after Forsyth 1959, 1966; Goldthwait et al. 1961).

the formation of Early Lake Erie, the Niagara Escarpment has recovered isostatically, raising both the outlet and consequently the level of Lake Erie, and drowning the Maumee Valley westward to near Perrysburg, OH (Lewis 1969; Forsyth 1970, 1973; Coakley and Lewis 1985).

Although published work on northwestern Ohio is voluminous, little has been written on the Maumee River or its terraces. Gilbert (1873), Leverett (1902), and Forsyth (1970) have described the general geologic setting of the Maumee Valley, and Cross and Weber (1959) and Forsyth (1968) have discussed many of the flooding problems along the Maumee River.

Information on the terraces of the Maumee consists primarily of casual remarks in studies of other features. Carman (1930) described two abandoned channels, one midway between Waterville and Maumee (Fig.1), the other in Waterville. The channel in Waterville has also been discussed by Farnsworth (1958). Forsyth (1960) described a terrace deposit at the Toledo Edison Dam site not far from the Maumee-Auglaize confluence. Soils along the Maumee Valley are described by Baker et al. (1960) who report that Digby, Millgrove, and Fulton Sandy Subsoil Variant soils occur on "high terraces along the Maumee," and by Stone et al. (1980) who found that Digby, Rimer, and Spinks soils form on stream terraces in the Maumee Valley.

MATERIALS AND METHODS

All flat surfaces along and within the Maumee Valley between the Ohio-Indiana state line and Perrysburg, OH, that might be sections of flood plains or remnants of river terraces, as well as related features such as river deposits and bedrock outcrops, were mapped in the field on 7.5-minute topographic maps. Soils maps (Baker et al. 1960, Flesher et al. 1974, Rapparlie et al. 1966, Stone et al. 1980 [and Flesher and Crowner unpubl.]) were used extensively to supplement field observations of sediment type. Depth to bedrock was determined from outcrops observed in the field, water-well logs, and bedrock-surface maps by Bush (1966) and Nielsen (1977).

Terraces were distinguished from the modern flood plain by their positions above clearly identifiable flood plain in areas where both are well developed. In addition, following the classic distinction that terraces occur above flood level, flat features were identified as terraces if they stood above the flood levels determined from United States Geological Survey (U.S.G.S.) gaging-station records from Antwerp and Waterville (data supplied by U.S.G.S. Water Resources Division). These terraces lacked soils characteristically developed on flood plains (such as Genessee, Ross, Shoal, and Sloan soils), or lacked field evidence of flood debris and ice-floe scars on tree trunks. It was recognized that, in some cases, low terraces can

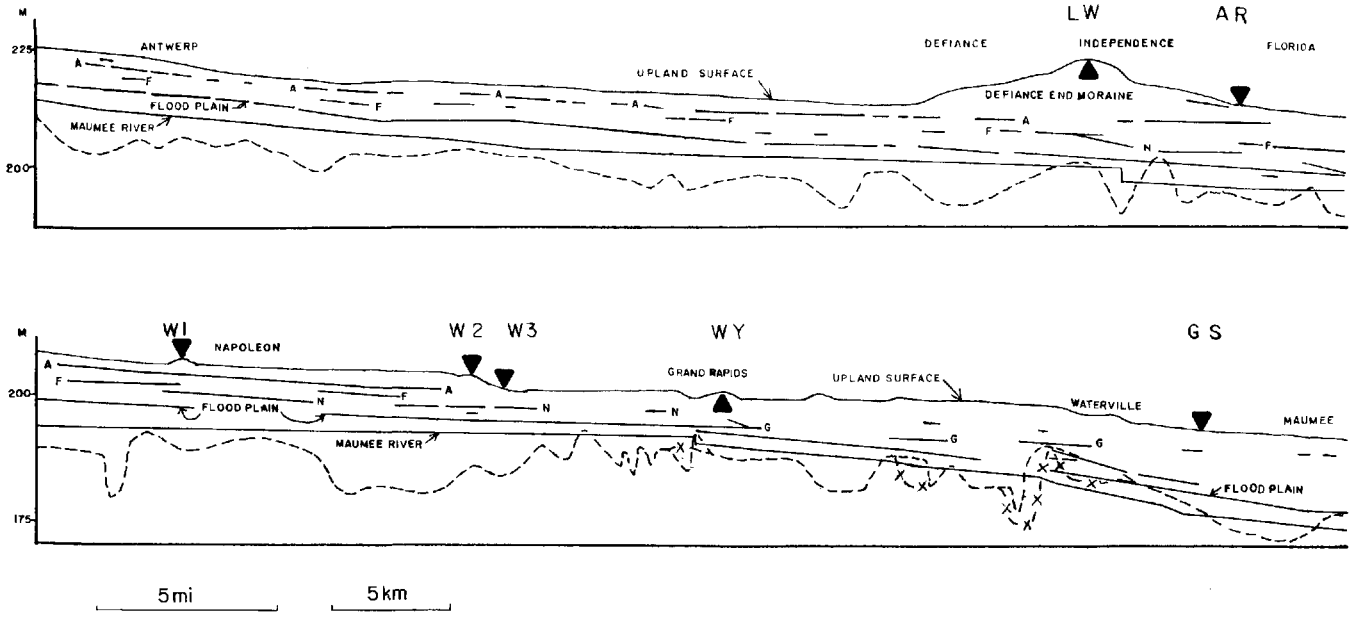

FIGURE 2. Long profile of the Maumee Valley from the Ohio-Indiana state line to Maumee, OH. A = Antwerp Terrace, F = Florida Terrace, N = Napoleon Terrace, G = Grand Rapids Terrace.
--- = Bedrock surface (-x- indicates south shore of river). Glacial Lake Shore (LW = Whittlesey, AR = Arkona, W1 = Warren I, W2 = Warren II, W3 = Warren III, WY = Wayne, GS = Grassmere).

become flooded during exceptionally high floods, a condition that may occur especially in the very-low-gradient portion of the river downstream from Grand Rapids. However, farther upstream, a flood plain with one or more of the flooding characteristics listed above was regularly found below the terraces.

RESULTS

Four major levels of paired terraces were traced for considerable distances along the Maumee Valley. In addition, short segments of six other terraces were recognized (Figs. 2, 3).

The Antwerp Terrace

The highest of the four major terrace levels, the Antwerp Terrace, was named for well-developed remnants of this terrace in the city of that name at an elevation of 221 m (724 ft) (Figs. 3, 4). This terrace does not become flooded, even in high-magnitude, low-recurrence-interval floods. Nowhere does this terrace lie less than 7.6 m (25 ft) above river level, and the highest flood recorded at the Antwerp gaging station reached a maximum gage height of only 6.2 m (20.24 ft).

The Antwerp Terrace consists of two sections based on differences in gradient, morphology, and terrace composition. Basically, the western section is characterized by broad constructional terraces or benches, whereas the eastern section is composed of a series of anastomosing channels. The western section extends from near the state line to 1.0 km (0.6 mi) upstream of the

TERRACE	LENGTH MAPPED	ELEVATION ABOVE RIVER	GRADIENT	LOWEST DOWNSTREAM ELEVATION	CORRELATED TO
ANTWERP					
West End	58 km (36 mi)	7.6-13.7 m (25-45 ft)	0.25-0.26 m/km (1.3-1.4 ft/mi)	207 m (678 ft)	Lakes Warren I & II
East End	11 km (7 mi)	8.5-13.1 m (28-43 ft)	0.38 m/km (2 ft/mi)	203 m (667 ft)	
FLORIDA	68.8 km (43 mi)	6.1-9.5 m (20-31 ft)	0.26 m/km (1.4 ft/mi)	201.2 m (639 ft)	Lake Wayne
NAPOLEON	51.2 km (32 mi)	4.6-7.3 m (15-23 ft)	0.19 m/km (1 ft/mi)	194.8 m (639 ft)	Lake Grassmere
GRAND RAPIDS	17.6 km (11 mi)	4.3-8.8 m (14-29 ft)	0.23 m/km (1.2 ft/mi)	191.8 m (629 ft)	Rock Defended

FIGURE 3. Characteristics of the major Maumee River Terraces.

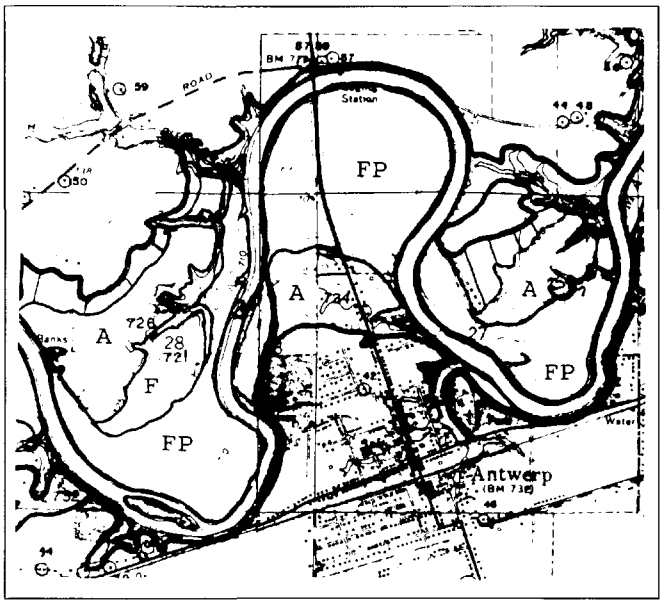

FIGURE 4. The Antwerp Terrace at Antwerp, OH.
A = Antwerp Terrace, F = Florida Terrace, FP = Flood plain.

Napoleon city limits and is characterized by distinct benches capped by alluvial sands and silts that have been partially covered by slope-wash deposition along their back sides. Soils found on this section of the terrace are Fulton Sandy Subsoil Variant, Digby, Millgrove, and Haney soils.

The eastern section of the Antwerp Terrace extends from 0.97 km (0.6 mi) upstream of the Napoleon city limits east to 4.2 km (2.6 mi) downstream of Napoleon. This section of the terrace is represented by a broad (up to 1.6 km [1.0 mi] wide) belt of shallow anastomosing channels, cut 1.5 to 2.4 m (5 to 8 ft) into the till upland. These channels are continuous with the distinct benches to the west. Little evidence of alluvial sedimentation was observed in these channels; soils found here are almost entirely Hoytville, which develops in till, containing a few isolated patches of Millgrove soil, which is developed in terrace sediments.

The Florida Terrace

The second of the four major paired terraces, lying immediately below the Antwerp Terrace, is named the Florida Terrace for well-developed remnants found in Florida, OH, at an elevation of 205.2 m (673 ft) (Figs. 3, 5). This terrace lies 1.5 to 3 m (5 to 10 ft) below the Antwerp Terrace and 6.1 to 9.5 m (20 to 31 ft) above present river level.

The Florida Terrace is generally less altered by subsequent erosion and slope-wash deposition than is the

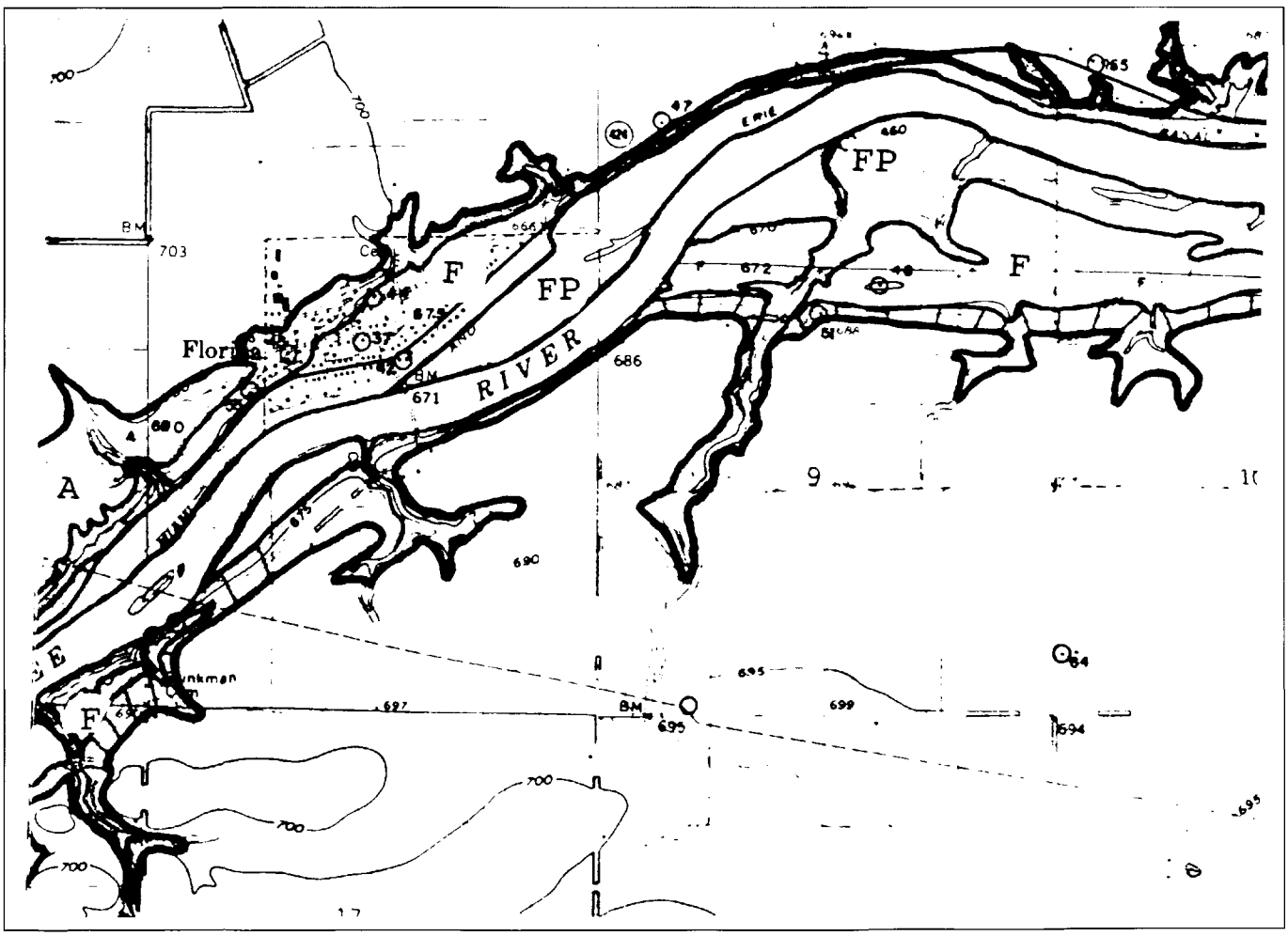

FIGURE 5. The Florida Terrace at Florida, OH. F = Florida Terrace, A = Antwerp Terrace, FP = Flood plain.

Antwerp Terrace. Terrace sediments are largely sand having some silt, represented by Millgrove, Haskins, Haney, and Digby soils.

The Florida Terrace does not become flooded. It stands between 6.1 and 9.5 m (20 and 31 ft) above river level and has an elevation of 219.5 m (720 ft) 1.6 km (1.0 mi) east of Antwerp, this is 1.2 m (4 ft) above the highest flood (1959) recorded there. None of the mapped soils on the Florida Terrace are flood plain soils.

The Napoleon Terrace

The third of the paired terrace levels lies immediately below the Florida Terrace and is named the Napoleon Terrace for remnants found in the town of Napoleon at an elevation of 201.2 m (660 ft) on the north side of the river (Figs. 3, 6). It lies about 1.5 m (5 ft) below the Florida Terrace and between 4.6 and 7.3 m (15 and 23 ft) above river level. The Napoleon Terrace converges with the river downstream, standing 7.0 m (23 ft) above the river southeast of Florida, and dropping to 4.6 m (15 ft) above river level just west of Grand Rapids.

The materials capping the Napoleon Terrace consist of sands and silts. Representative soils on this terrace are Digby and Haney soils.

Although no gaging-station records are available for this section of the river, field evidence suggests that the Napoleon Terrace lies above flood level. No flood plain soils occur on the terrace and no ice-scarred trees or other evidence of flooding were found.

Two short terrace segments that may correlate with the Napoleon Terrace were found downstream from the last certain remnant of this terrace. These two segments occurred at elevations of at 197.6 m (648 ft) and 194.8 m (639 ft), 4.8 km (3.0 mi) upstream from and 1.6 km (1.0 mi) south of Waterville, respectively. Although these two downstream segments appear to fall on the projected profile of the Napoleon Terrace, the correlation with that terrace is tentative because of the drastic increase in the river's gradient at Grand Rapids and the presence of bedrock outcrops which form rock-defended terraces in the area between Waterville and Grand Rapids.

The Grand Rapids Terrace

The fourth and lowest of the paired terraces is named the Grand Rapids Terrace for a remnant in that city at an elevation of 196.0 m (643 ft) (Figs. 3, 7). It begins on the north side of the river at the Grand Rapids Dam at an elevation of 195.4 m (641 ft) and extends

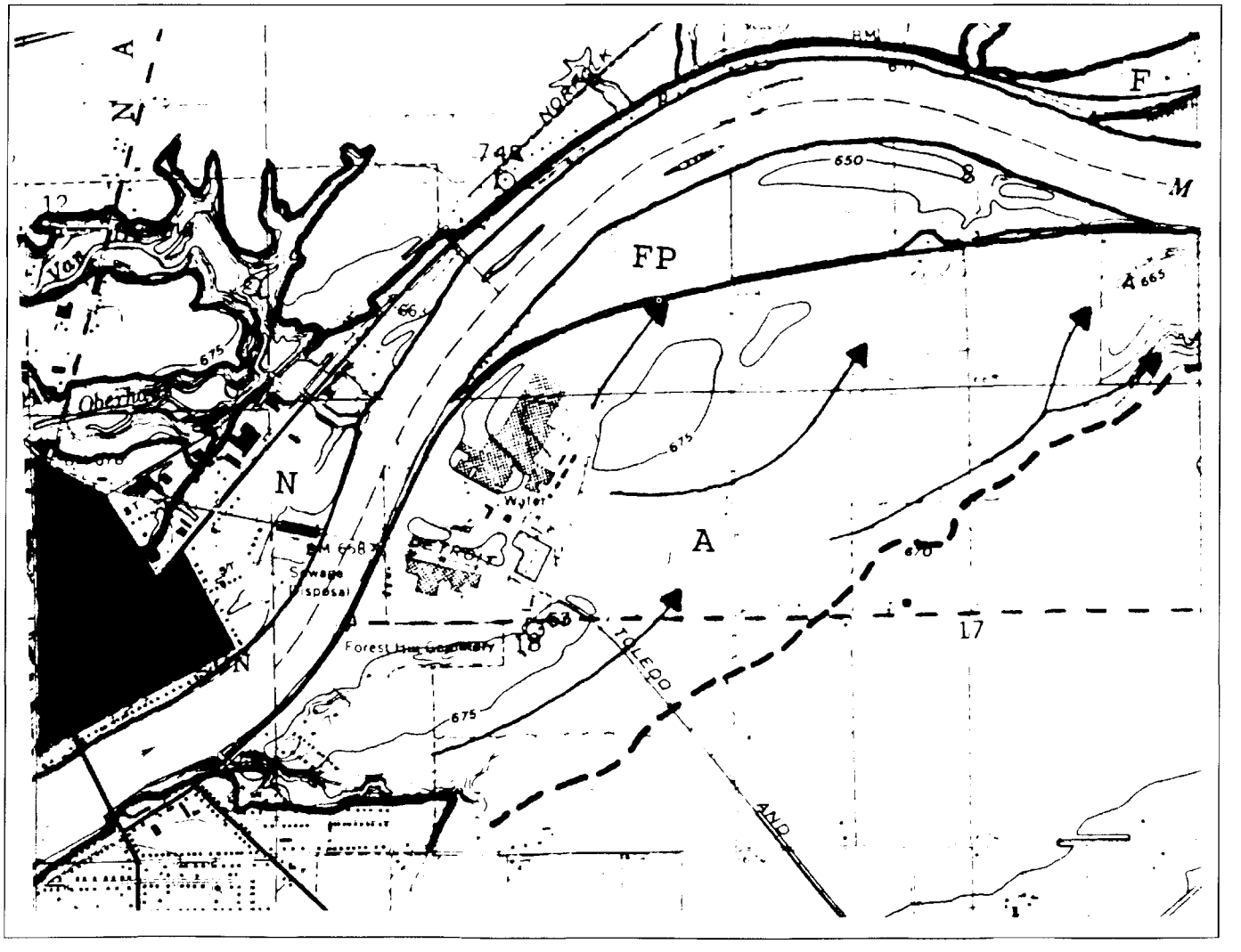

FIGURE 6. The Napoleon Terrace at Napoleon, OH.
N = Napoleon Terrace, F = Florida Terrace, A = Antwerp Terrace, FP = Flood plain. Arrows indicate erosional channels.

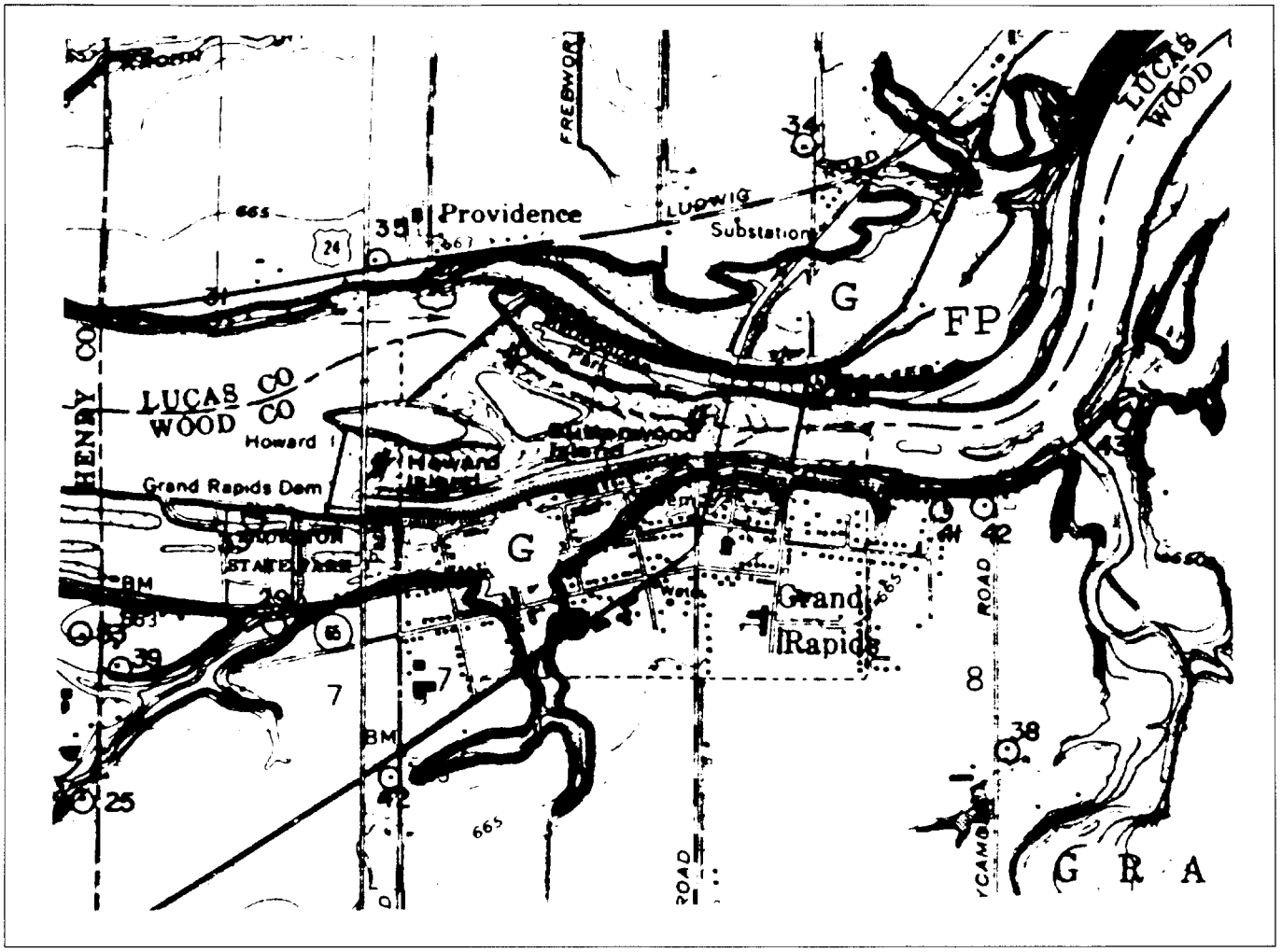

FIGURE 7. The Grand Rapids Terrace at Grand Rapids, OH. G = Grand Rapids Terrace, FP = Flood plain.

downstream for 17.7 km (11 mi) to Waterville, where it ends in an abandoned channel cut into the Tymochtee Dolomite at an elevation of 191.8 m (629 ft). This terrace is continuous with the flood plain above the Grand Rapids Dam, but below the dam it stands 1.5 to 7.3 m (5 to 24 ft) above the level of the active flood plain (Fig. 7). The profiles of the terrace and the river diverge downstream. Just below the dam the terrace stands 4.3 m (14 ft) above river level, and in Waterville the terrace stands 8.8 m (29 ft) above the river.

The composition of the Grand Rapids Terrace is mostly silt with some sand and clay that is underlain by shallow bedrock in places: by the Devonian Dundee Limestone at the Grand Rapids Dam, and by the Silurian Tymochtee Dolomite in Waterville. Typical soils developed in these sediments are Dunbridge and Digby soils.

Gaging-station records indicate that several parts of the upstream segments of the Grand Rapids Terrace which stand closer to river level were flooded during the high floods of 1913, 1959, and 1978. Despite these floodings of small sections of the terrace by high-magnitude, low-recurrence-interval floods, the terrace, including the segments at lower elevations, is well above the level of the average annual flood and stands between 1.8 and 7.3 m (6 and 24 ft) above a well-developed flood plain for most of its length.

Three short features downstream of Waterville may correlate with the Grand Rapids Terrace. The first of these is a short channel cut into the upland near Hull's Crossing at an elevation of 190.9 m (626 ft). The other two remnants are short narrow benches in Maumee just below Broadway Avenue at elevations of 190.9 and 189.9 m (626 and 623 ft). However, it is unclear whether these latter two are true terrace remnants or artifacts of urbanization.

Local Terraces

In addition to the four main terraces, several small terraces were mapped. Two lie below the Grand Rapids Terrace in Waterville. The longest of these begins on the west side of the abandoned electric railway bridge, runs though Waterville along River Road, and ends in the abandoned channel midway between Waterville and Maumee. The second consists of two short remnants on the south side of the river.

Two short abandoned channels occurring above the major terraces were found in the western part of the Maumee Valley. The westernmost of these is located 3.2 km (2 mi) east of the state line and stands 1.2 m (4 ft)

above the Antwerp Terrace. The second was found 4.0 km (2.5 mi) downstream of the Independence Dam where it was cut 1.5 m (5 ft) into the Defiance End Moraine. This channel stands 3.0 m (10 ft) above the level of the Antwerp Terrace there.

DISCUSSION

The two short abandoned upland channels mapped in the western portion of the study area are interpreted to represent the initial stages of erosion on newly exposed lake bottom prior to the time represented by the Antwerp Terrace. They are preserved because they lie outside of the Maumee Valley, protected from subsequent erosion by the river.

The Antwerp, Florida, and Napoleon terraces, and the abandoned channel cut into the Defiance End Moraine are correlated with different levels of the ice-dammed lake which occupied the Erie Basin in late Wisconsinan time. In contrast, the Grand Rapids Terrace and the short terraces below it in Waterville are interpreted to be rock-defended terraces.

None of the major Maumee River terraces can be correlated to the first five ice-dammed lakes in the Erie Basin, as most of these lakes (Glacial Lakes Maumee I, II, and III, Arkona, and Whittlesey) occurred at elevations higher than the upland surrounding the Maumee River. Glacial Lake Arkona (216-212 m [710-695 ft]) would have exposed the westernmost part of the Maumee Valley, but is interpreted to have been very short-lived (Calkin and Feenstra 1985), so any valley cutting at that time would have been limited, and the area was soon inundated by Lake Whittlesey, which extended almost to the state line. The upland channel cut into the Defiance End Moraine ends just above the 212 m (695 ft.) shoreline of Lake Arkona (Fig. 2) and is the only mapped remnant that could correlate with this short-lived lake.

The Antwerp Terrace is correlated with Glacial Lakes Warren I and II on the basis of the 206.7 m (678 ft) elevation at the downstream end of the constructional benches which form its western section. The shallow channels of the eastern part of the Antwerp Terrace probably represent the initial stages of downcutting as lake level dropped to the level of Glacial Lake Wayne or may be the result of seasonal fluctuations in lake level.

The Florida Terrace, having a downstream elevation of 201 m (660 ft), correlates best with Glacial Lake Wayne. This correlation presents a problem, however, as Lake Wayne is thought to have been very short-lived (Hough 1966, Calkin and Feenstra 1985, Eschman and Karrow 1985). Thus, whether Lake Wayne persisted long enough to have produced such a distinct terrace may be questioned, though radiocarbon dates elsewhere in the lower Great Lakes area (Coakley and Lewis 1985) suggest that none of the glacial lake stages lasted very long. In addition, following the Wayne stage, lake level is believed to have risen to 203 m (665 ft) during Warren III stage (Calkin and Feenstra 1985). This would have flooded the lower portion of the Florida Terrace to a position just east of Napoleon. Under these conditions, some reworking of older sediment and the deposition of some lacustrine silts and clays on the flooded portion of the terrace should have occurred, but no such effects were observed. The absence of any evidence of lake modification of the Florida Terrace may indicate that Lake Warren III was especially short-lived and did not significantly affect the valley.

The Napoleon Terrace was traced downstream with confidence only as far as 1.6 km (1 mi) upstream of the Grand Rapids Dam, where it has an elevation of 198.8 m (652 ft). Because no bedrock control of this terrace can be demonstrated and because the terrace lies below the Florida Terrace (correlated with Lake Wayne), the Napoleon Terrace is tentatively correlated with Glacial Lake Grassmere (195 m [640 ft]). If the two terrace remnants at 194.8 m (648 ft) just west of Waterville and 194.8 m (639 ft) south of Waterville are indeed a part of the Napoleon Terrace, the correlation of this terrace with Lake Grassmere becomes more certain.

The Grand Rapids Terrace is a rock-defended terrace, with its level controlled for 17.6 km (11 mi) upstream by outcrops of resistant Silurian-age Tymochtee Dolomite at Waterville. In the Grand Rapids area, the terrace is underlain and protected by outcrops of the Devonian Dundee Limestone. The bedrock surface in the Waterville area slopes gently to the southeast (Fig. 2), thus, at least early in its history, the Maumee River could have downcut more easily on the southeastern side of its bed, which would have caused the river to offset to the southeast and ultimately to abandon its former channel through Waterville. The Grand Rapids Terrace must be post-Grassmere (Lundy?) in age, because of its elevation below that of the Napoleon Terrace. The two short terrace remnants located just below the Grand Rapids Terrace in Waterville and the abandoned channel midway between Waterville and Maumee are cut into the Silurian Tymochtee Dolomite and are also rock-defended terraces.

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